

The University of Chicago

**GEOLOGY OF A PORTION OF THE
SAVANT LAKE AREA, ONTARIO**

**A PART OF A DISSERTATION SUBMITTED TO THE
FACULTY OF THE DIVISION OF THE PHYSICAL
SCIENCES IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY**

**DEPARTMENT OF GEOLOGY AND PALEONTOLOGY
1935**

**By
GORDON RITTENHOUSE**

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ABSTRACT

Approximately 18,000 feet of sediments, divisible into six members, and 27,000 feet of volcanics below and above these sediments make up the early pre-Cambrian geologic column in the Savant Lake area. These rocks have been folded, intensely faulted, and subjected to at least one period of granitic intrusion and two periods of basic dike intrusion. In the sediments, and especially in the lavas, primary structures were found to be of great value in working out the structure. Correlation was attempted only with the Sioux Lookout and Sturgeon Lake areas.

The genesis of the two iron-bearing members is considered. Microscopic evidence suggests the possibility of formation through selective replacement by hydrothermal solutions. Other evidence points to a syngenetic origin.

INTRODUCTION

In the summer of 1927 Dr. E. S. Moore and assistants mapped what is now known as the Savant Lake area for the Ontario Department of Mines.¹ Due to the size of the area (approximately 1,000 square miles) and limited time, the geological work was necessarily of a reconnaissance nature. This paper deals with a portion of that area, roughly bounded by latitudes $50^{\circ}19'$ and $50^{\circ}30'$ and longitude $90^{\circ}42'$ and $90^{\circ}25'$, including Poisson and Jutten townships and the two unsurveyed townships to the west. The object of the work was:

1. To establish the sequence of formations, their thickness, conditions of deposition, and relations to the basic lavas and to the intrusives.
2. To study the iron formation and, if possible, determine its genesis.
3. To work out the structural geology.

As the field work progressed and the intricate nature of the structural relationships became apparent, the writer realized that in the time available it would be impossible to map the entire area in as great detail as originally planned. At the same time he realized that

¹ E. S. Moore, "Lake Savant Area, District of Thunder Bay," *Ont. Dept. Mines*, Vol. XXXVII, Part IV (1928), pp. 53-82.

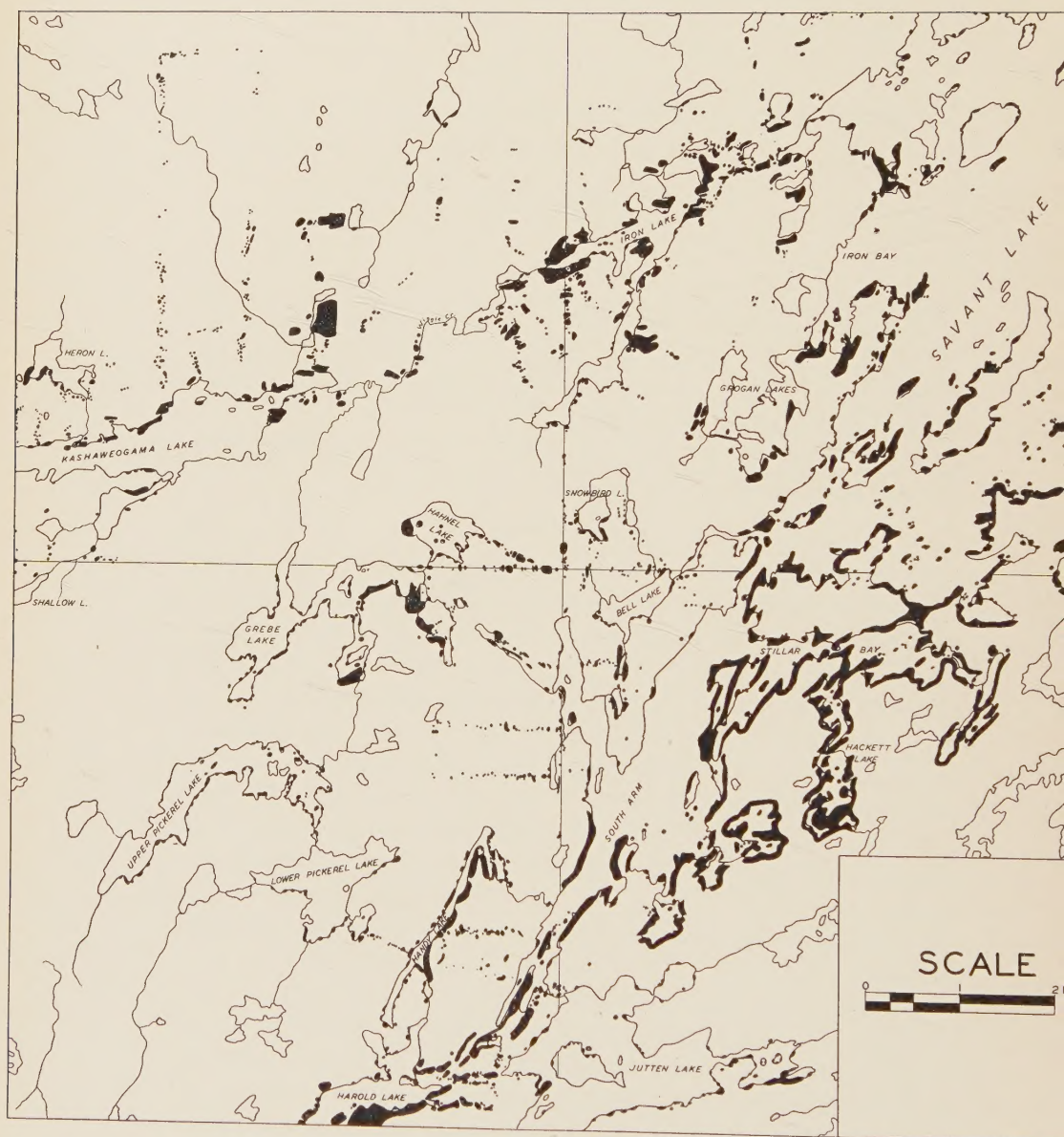


FIG. 1.—Areal distribution of outcrops visited in the Savant Lake region

the major structures were of large dimension and could not be satisfactorily worked out in an area smaller than that originally chosen. The geological work is, therefore, much less complete than desired.

PREVIOUS WORK

Earliest reference to the Savant Lake area was made by McInnes,² who in 1901 visited the main lake during the course of a geological reconnaissance of the country lying between Sturgeon Lake and Lac Seul. In the same year Sullivan³ made a hasty examination of the glacial gravels on islands of the main lake, but no bedrock observations were recorded. In 1903 Miller⁴ traversed Savant Lake and reported in some detail on the gold found in the glacial drift. Reference was also made to the magnetite deposits.⁵ In 1906 Collins made a more complete reconnaissance of the district, recorded his observations in two papers,⁶ and published the first geological map of the area. Collins described the bands of conglomerate and indicated the distribution of the iron-bearing formation, the sediments, and the greenstones, all of which were combined as Keewatin in the mapping.

In 1909 Moore, engaged in a geological survey of the magnetite deposits of the Savant Lake area, presented a relatively detailed report and a map of an area lying between Kimmewin and Savant lakes.⁷ The various types of rocks were described, the structural geology considered, and the magnetite deposits discussed from the standpoint of composition and genesis. In 1926 lode deposits of gold were discovered, and during the following summer Moore undertook

² W. McInnes, "Region South-east of Lac Seul," *Can. Geol. Surv. Summary Rept.*, Vol. XIV, Part A (1910), pp. 94-95.

³ W. T. Gibson, *Ont. Bur. Mines*, Vol. XI (1902), p. 18.

⁴ W. G. Miller, "Mines of Northwestern Ontario," *Ont. Bur. Mines, Ann. Rept.*, 1903, pp. 87-90.

⁵ *Ibid.*, p. 313.

⁶ W. H. Collins, "On Surveys along the National Transcontinental Railway Location between Lake Nipigon and Lac Seul," *Can. Geol. Surv. Summary Rept.* (1906), pp. 106-7; "A Geological Reconnaissance of the Region Traversed by the National Transcontinental Railway between Lake Nipigon and Clay Lake, Ontario," *Can. Geol. Surv. Bull.* 1059 (1909), pp. 34-37.

⁷ E. S. Moore, "Lake Savant Iron Range Area," *Ont. Bur. Mines 19th Ann. Rept.*, Vol. XIX, Part I (1910), pp. 173-92.

a resurvey of the entire Savant Lake area. This report⁸ is by far the most comprehensive and accurate study of the Savant Lake area published. The general essentials of the geology were recognized by Moore.

GENERAL GEOLOGY

GENERAL STATEMENT

The stratigraphic succession as now known in the Savant Lake area is shown in the accompanying geologic column (Table I). The oldest rocks, here named the "Jutten volcanics" from their excellent exposure in Jutten Township, indicate a period of intense volcanic activity during which was formed a great volume of intermediate and basic flow rocks with some interbedded tuffs, agglomerates, conglomerates, graywackes, and acid flows. This series was tilted or folded, intruded by granitic rocks, and then deeply eroded.

Upon this erosion surface, near a region of strong relief, was deposited a thick terrestrial conglomerate composed of detritus from the greenstone-granite terrain. After the deposition of a thousand feet of this conglomerate, conditions changed greatly, probably owing to the initiation of volcanism, and a very thick conglomerate deficient in granite detritus was deposited. These coarse clastics, forming the Lower Savant series, were followed by deposition of four finer-grained members, two containing interbedded iron formation⁹ and two essentially graywacke,¹⁰ which may be designated the "Upper Savant series." A period of erosion followed the deposition of these dominantly sedimentary rocks. Then volcanic activity was again renewed; and a very thick series of tuffs (the Handy Lake volcanics), acid to intermediate flows, conglomerates, and agglomerates, was formed.

The rocks of this area were then intruded by basic dikes and stocks, folded, faulted, and later intruded by granites. Erosion, intrusion of diabase dikes, and more erosion followed. During Pleistocene time the area was partly covered by glacial deposits.

⁸ Moore, "Lake Savant Area, District of Thunder Bay," *loc. cit.*

⁹ In this paper "iron formation" refers to particular laminae, bands, or lenses in which magnetite forms an essential portion of the rock, whereas "iron-bearing formation" refers to rock made up in part of iron formation.

¹⁰ Graywackes in the Savant Lake area contain a high percentage of grains derived from acid to intermediate fine-grained flows.

TABLE I
STRATIGRAPHIC SUCCESSION IN THE SAVANT LAKE AREA

Formation		Character	Thickness* in Feet	
Pleistocene and Recent		Drift, glacio-fluvial deposits, peat		
Unconformity				
Keweenawan (?)		Diabase dikes		
Acid intrusives		Granite, porphyritic granite, acid dikes, aplite, etc.		
Basic intrusives		Diorite and meta-diorite dikes and plutonics		
Handy Lake volcanics		Tuff, agglomerate, rhyolite, dacite, porphyry, graywacke, arkosite, conglomerate	10,000	
Unconformity (?)				
Savant Series	Upper	Upper graywacke member	Graywacke, slate, tuff, arkosite, grit, quartzite	3,000
		Upper iron-bearing member	Graywacke, arkosite, iron formation, argillite	1,000
		Lower graywacke member	Mainly banded graywacke, and argillite with some arkosite	3,000
		Unconformity (?)		
		Lower iron-bearing member	Graywacke, arkosite, iron formation, argillite, quartzite, grit, tuff, conglomerate	2,000
	Lower	Upper conglomerate member	Boulder, cobble, and pebble conglomerate, graywacke, tuff, arkosite. No granite boulders	8,000
		Lower conglomerate member	Boulder, cobble, and pebble conglomerate, graywacke, arkosite. Granite boulders common	1,000
Unconformity				
Jutten volcanics		Basic and intermediate lavas predominant, iron formation, agglomerate, tuff, conglomerate, graywacke, rhyolite	17,000	

* Thickness based on measurement across the strike on beds dipping at about 90°. (No repetition by folding or faulting observed.)

JUTTEN VOLCANICS

The Jutten volcanics are widely exposed in an area southeast of Savant Lake and in an area north of Kashaweogama Lake (Fig. 2). A great variety of rock types is present. Most common are basic and intermediate lavas which commonly show ellipsoidal or pillow structure. Interbedded with these rocks, which are estimated to make up more than 85 per cent of the entire formation, are more acid lavas, agglomerates, tuffs, conglomerates, graywackes, and iron formation. Some porphyritic basic and intermediate rocks are probably sill-, stock-, or dike-like intrusives into the lavas. The rocks have been altered to some extent, and in some places they have been rendered extremely schistose by shearing.

It has been common practice to combine all of these types of rocks and their metamorphic equivalents under the loose term "greenstone" and to assign them without other evidence to the Keewatin period. The Jutten volcanics are of the "Keewatin" type; and, since practically every report on the pre-Cambrian shield contains a more or less detailed description of such series, it seems unnecessary to do more than point out the similarity and to refer to the best petrographic descriptions in the literature.¹¹

Structure of the Jutten volcanics.—The writer used the shapes of the pillow structures for determining tops and bottoms of flows and found that the results obtained were very consistent. In the southeast band of the Jutten volcanics, twenty-eight determinations scattered throughout the area of outcrop showed the tops of the flows to be northwest in every instance. Two determinations in which the contacts between flows were observed also showed top to the northwest. Determinations could not be made on many outcrops, owing to the small area of exposure, distortion due to folding or shearing, or indeterminate shape. No outcrop in which the shape was satisfactory for purposes of determination showed the top of the beds to the southeast. The evidence of the pillow lavas shows that the Jutten volcanics in this area form a monoclinical structure with the basal part of the formation to the southeast.

¹¹ Moore, "Lake Savant Area, District of Thunder Bay," *loc. cit.*, pp. 57-60; C. R. Van Hise and W. S. Bayley, "The Marquette Iron-bearing District of Michigan," *U.S. Geol. Surv. Mono.* 27 (1897), pp. 490-517; A. C. Lawson, "The Archean Geology of Rainy Lake, Restudied," *Can. Geol. Surv. Mem.* 40 (1913), pp. 45-50.

In the area of Jutten volcanics north of Kashaweogama Lake pillow lavas are also abundant. Six determinations made during two traverses across the strike of these greenstones all show tops of the flows to the northwest. This attitude was the opposite from that expected; and determinations were made with very great care, none being accepted unless independent conclusions by the writer and his assistant were in agreement. These observations, together with other evidence, suggests the existence of a fault contact with the conglomerate of the Savant series (p. 476). The Jutten volcanics north of Kashaweogama Lake, therefore, form a monoclinial structure striking N. 55° E., with the top of the flows to the north.

If these interpretations of the structure of the volcanics are correct, the formation, measured along a line normal to the strike of the beds from MacNamara Point to the contact with the Jutten Lake batholith, has an apparent thickness of approximately 13,000 feet. Three miles to the north measurement normal to the strike gives an apparent thickness of approximately 17,000 feet. North of Kashaweogama Lake the thickness is about 16,000 feet. In all three cases the total thickness was not determinable because both the top and the base of the formation have been removed by erosion, faulting, or granitic intrusion. There may be some duplication of beds by faulting, but there can be no duplication due to folding.

LOWER SAVANT SERIES

LOWER CONGLOMERATE MEMBER

The lower conglomerate member is best exposed on the north side of MacNamara Point. Along the shore is an almost continuous exposure of conglomerate which shows the rounded granite boulders characteristic of this member. Measured across the strike the thickness is between 600 and 700 feet. This outcrop forms the most northerly exposure of the lower conglomerate member in the southeastern portion of the map area. For, on the north shore of Stillar's Bay, less than a thousand feet away and directly in strike line, the conglomerate is very schistose and of entirely different character, belonging to the upper conglomerate member, the lower conglomerate member apparently being faulted out by an east-west fault of considerable magnitude (p. 477). From MacNamara Point the lower conglomerate has been traced southwest along the South Arm, along

LEGEND

EARLY PRE-CAMBRIAN

POST-SAVANT INTRUSIVES



ACID INTRUSIVES



BASIC INTRUSIVES

HANDY LAKE VOLCANICS



ACID LAVAS AND AGGLOMERATES

SAVANT SERIES



UPPER GRAYWACKE MEMBER



UPPER IRON-BEARING MEMBER



LOWER GRAYWACKE MEMBER



LOWER IRON-BEARING MEMBER



UPPER CONGLOMERATE MEMBER



LOWER CONGLOMERATE MEMBER

JUTTEN VOLCANICS



BASIC LAVAS AND IRON FM.

SYMBOLS



GEOLOGIC BOUNDARY ASSUMED



FAULT



TOP OF BEDS DETERMINED BY GRADATION OF GRAIN OR CROSS-BEDDING



TOP OF FLOWS DETERMINED BY SHAPE OF PILLOWS



STRIKE OF BEDS





the west shore of Jutten Lake, to the place where it leaves the map area east of Harold Lake.

A second band of conglomerate belonging to this lower member is found north of Kashaweogama Lake. On the east the band probably ends against the largest cross fault (p. 477). From here the belt trends west and slightly south, is offset by several cross faults, and narrows rapidly, disappearing entirely just east of Heron Lake. A part of the reduction in thickness is due to faulting.

Petrography.—The lower conglomerate member is very uniform in character. In it occur boulders, cobbles, and pebbles of granite, feldspar- and quartz-porphyrines (forming not more than 35 per cent of the rock), and greenstones of various sorts. A few cobbles of vein quartz, hematite or limonite, and siliceous rock resembling jasper were found. Granite boulders up to 25 inches in diameter and greenstone boulders up to 15 inches in length were noted. Fragments of the light-colored rocks are well rounded, but the greenstone fragments, where distinguishable, tend to be lens-shaped, and where the formation is schistose are greatly elongated, whereas the leucocratic rocks are much less deformed. In the field the matrix appeared to be mainly fine-grained graywacke, though where the lower conglomerate member outcrops on Jutten Lake the matrix is more arkosic but does not seem to show any evidence of metamorphism due to the nearby granite.

Relation to underlying formation.—Direct observation of the relation of the Savant series to the Jutten volcanic¹² is rarely possible. The contact between them was observed at only one point, namely, in the southernmost exposures on the South Arm. A grayish, schistose rock intervenes; and as the conglomerate is approached, an occasional boulder may be seen. This belt of nondescript rock may represent a pre-conglomerate soil upon the greenstone. A similar occurrence has been described by Pettijohn from the Sioux Lookout area.¹³

Since granites are thought to be intruded under a minimum cover

¹² Timiskaming-Keewatin boundary of Moore. Interpreted as disconformity by him in 1931.

¹³ F. J. Pettijohn, "The Conglomerate of Abram Lake, Ontario, and Its Extensions," unpublished manuscript (1930), p. 121.

of 2,500 feet and since granite boulders occur in the basal phase of the conglomerate, it seems likely that removal of at least 2,500 feet of material must have taken place before granite boulders would have been available for formation of the conglomerate. If the granite was pre-Jutten in age, probably an even greater amount of material was removed.

Further evidence of a significant break is furnished by the discordance of strike between the greenstone and conglomerate east of the South Arm. The strike of the conglomerate is approximately N. 20° E., whereas the greenstones of that area strike approximately N. 55° E. No positive evidence of faulting along this contact was observed. The simplest explanation calls for tilting and erosion of the greenstones before the deposition of the conglomerate. The amount of erosion required would have been great.

Conditions of deposition.—The lower conglomerate member is usually over 600 feet in thickness but in some places may be two or three times as thick. The rock is characteristically a boulder conglomerate with but few interbedded finer-grained layers. The boulders are exceptionally well rounded and do not show any evidence of glacial origin. The only environment in which such conglomerates are deposited today is at the foot of high mountains, as alluvial and piedmont deposits. Pettijohn¹⁴ and others have suggested this method of formation for thick pre-Cambrian conglomerates, and the conglomerate of the Savant series appears to be of the same type and to have formed under similar conditions.

UPPER CONGLOMERATE MEMBER

The most extensive band of the upper conglomerate member extends from the west boundary of the map area, just north of Kasha-weogama Lake, east and a little north for a distance of 10 miles until it leaves the area just west of Savant Lake. This band is very persistent, though cut by numerous north-south faults and intruded by the porphyritic granite north of Iron Lake. It shows great variation in thickness. North of Wiggle Creek it is approximately 8,000 feet in thickness; north of Iron Lake the thickness is not less than 6,500

¹⁴ F. J. Pettijohn, "Conglomerate of Abram Lake, Ontario, and Its Extensions," *Geol. Soc. Amer. Bull.* 45 (1934), pp. 500-501.

feet; and east of Iron Lake the thickness exceeds 5,000 feet. West of the major cross fault north of Kashaweogama Lake the thickness is much reduced, being 2,500 feet just north of the east end of Kashaweogama Lake and less than 1,200 feet south of Heron Lake.

A second, thinner band of this upper member parallels the east shore of the South Arm from the narrows to Harold Lake (Fig. 2). On the northwest end of MacNamara Point a thickness of 700–800 feet is exposed. West of Jutten Lake, where the upper portion of the formation is dominantly arkosite, the thickness is about the same.

Petrography.—This upper member is composed predominantly of conglomerate with a variety of interbedded rock types. Near the base of the member on the second lake north of Wiggle Creek the rock is a boulder conglomerate with lens-shaped fragments of various types of felsites and porphyries up to 5×2 feet in size. The matrix, composed of finer material of the same composition, forms a minor portion of the rock. Interbedded boulder, cobble, and pebble conglomerates; arkoses; graywacke; and tuff, with the finer-grained types prominent in the upper portion, comprise the main formation. One horizon of mixed crystal and lithic tuff about 350 feet thick has been traced for about a half mile north of Iron Lake. The difficulty of differentiating between tuff and arkosite suggests that some of the beds called arkosite in the field may actually be a mixture of tuffaceous material and arkose.

The upper conglomerate is characterized by the absence of granite boulders and the predominance of material derived from acid and intermediate flows.¹⁵ Greenstone fragments are rare except locally in the basal portion.

Conditions of deposition.—The conditions of deposition of the upper conglomerate member were probably very similar to those under which the lower conglomerate member was deposited, i.e., terrestrial accumulation in alluvial fans and other piedmont gravels adjacent to an area of strong relief. But the extreme thickness of the deposit and the composition of the detrital material derived from the adjacent high land indicates a change of conditions in that area. Granite and greenstone areas which had furnished detrital material to the

¹⁵ The porphyry fragments rarely carry quartz phenocrysts, eight thin-sections showing only one grain of quartz in either pebbles or matrix.

lower conglomerate member no longer supplied that material but instead furnished great volumes of rock of extrusive origin. Initiation of volcanic activity in the adjacent high lands, resulting in complete blanketing of the existing terrain, would not only explain the absence of granite and greenstone boulders but would also furnish the necessary extrusive rock fragments. The horizon of mixed tuff not only substantiates the hypothesis of volcanic activity but indicates that such action continued, at least intermittently, throughout the period of conglomerate deposition. The acid character of the extruded material, the fact that the conglomerates must have formed close to the highland but were not covered by the flows, and the great variation in thickness of the conglomerate suggests that the volcanic action was of the "mountain range" type.

UPPER SAVANT SERIES

Lying stratigraphically above the conglomerate is a thick series of fine-grained sediments which may be divided on the basis of lithology into a lower iron-bearing member, a lower graywacke member, an upper iron-bearing member, and an upper graywacke member. To facilitate petrographic description and discussion of conditions of deposition these four members have been grouped together.

The inferred distribution of these members is shown on the accompanying map. Where the upper iron-bearing member is missing, it is impossible to differentiate between the two graywacke members; and in these areas the rock has been mapped as undifferentiated Upper Savant series (Fig. 2). The estimates of thickness of these members are given in the stratigraphic column (Table I) and are probably subject to considerable correction but are believed to be of the right order of magnitude.

Petrography.—The sedimentary character of the major portion of the fine-grained sediments of the Savant series is everywhere quite apparent. The rocks exhibit a distinctly banded character owing to differences in color, and this banding has been accentuated by differential weathering which has given the rock a "ribbed" appearance on the weathered surface. Closer inspection shows the sediments to be composed of a variety of rock types, interbedded in bands which vary from a fraction of an inch to several feet in width. The differ-

ences in color between the layers are due to variations in composition and grain size. The subdivision of the finer sediments into members is based on the presence or absence of iron formation. With the exception of this material the four members are very similar petrographically.

They are characteristically composed of alternating layers of graywacke and argillite with some interbedded arkosite, quartzite, and slate. In places cobble and pebble conglomerate and grit bands occur at or near the base of the lower iron-bearing member. Gradation between bands and delicate lamination within the wider bands, especially in the iron formation, were observed. The magnetite-rich bands tend, however, to be sharply defined from the other sedimentary types, although two outcrops were discovered in which the magnetite-rich bands occurred as the top member of varvelike bands. These showed perfect gradation from graywacke, through argillite, to iron formation.

Under the microscope the coarser-grained phases were seen to be arkosite, graywacke, and tuffaceous graywacke, all showing some degree of metamorphism, but none so highly altered that the primary clastic textures were completely obliterated. The suite of mineral and rock fragments in the various types is very similar, the major difference being the proportion of the different constituents present. The rounded to subangular character shown by all grains indicates a sedimentary origin. The tuffaceous graywacke shows an admixture of more angular fragments and crystals which seem to have suffered very little, if any, transportation. These coarse-grained sediments, especially the graywackes and tuffaceous graywackes, are peculiar in that they contain a very high percentage of grains apparently derived from acid or intermediate flow rocks. The quartz, generally small in amount, is mostly present as a constituent of rock fragments rather than as separate mineral grains. This deficiency in quartz and the flood of acid or intermediate flow fragments would be expected from erosion of the volcanic terrain (or from direct volcanic contribution), which was apparently the source for the upper conglomerate member.

The rather subordinate matrix of the coarser clastics, probably originally of similar composition, is now recrystallized to a fine-

grained mosaic of chlorite or biotite, quartz, and feldspar. Magnetite occurs as scattered euhedral to subhedral metacrysts intermediate in size between the grains and the matrix. In two thin sections of graywacke some of the euhedral magnetite crystals lie half in the matrix and half in the sand grains, proving their later origin. Much smaller grains are concentrated in certain areas in the matrix. Occasional grains of euhedral tourmaline were also found.

The finer-grained rocks include argillite, tuffaceous argillite, and slate. The original textures of these rocks have been largely destroyed by recrystallization, but under the microscope the original bedded character usually can be inferred from the banding of the recrystallization minerals and from occasional coarser grains, obviously sedimentary. In the argillites are quartz, feldspar, magnetite, chlorite, sericite, biotite, carbonate, hematite, and tourmaline. There is some parallelism of the biotite, chlorite, and sericite. Tourmaline, which occurs as tiny, elongated, unfractured prisms, cuts across the schistosity. One thin section from the rhythmically banded iron-bearing formation on Iron Point, Savant Lake (lower iron-bearing member), shows more than twenty crystals in a medium-power microscopic field. The size and shape of these are such that they could not have been detrital and must, therefore, have been introduced. The unfractured character of the majority of the tourmaline crystals and their orientation transverse to the schistosity strongly supports the suggestion that their formation followed the folding of the sediments.

Magnetite was seen in small euhedral crystals scattered through the argillite and as relatively large metacrysts. The latter are commonly surrounded by an area, roughly proportional in diameter to the diameter of the magnetite crystals, in which there is a deficiency of biotite and chlorite compared to the surrounding rock.

The magnetite-rich bands of the iron-bearing members are composed of interstratified laminae of fine-grained quartz and magnetite. These laminae often show excellent gradation from one to another. The magnetite-rich portions of the rock are also rich in amphibole. Study of the polished sections shows some hematite intergrown with the magnetite. Slight gradation in the size of the quartz grains within the quartz laminae suggests that there was an original

textural difference in different parts of the quartz-rich laminae. This would be difficult to explain if the quartz was originally deposited as a chert.

Within the Upper Savant series are several minor units which deserve mention. Well up in the lower iron-bearing member is a bed of mixed trachyte tuff about 600 feet in thickness. In the lower graywacke member a dioritic flow or flows about 400 feet in thickness, underlain by a mixed andesite tuff of about the same thickness, was observed on the north shore of Kashaweogama Lake. Occurring also in the lower graywacke member is a little boulder conglomerate in bands, varying from about 100 feet in thickness east of Grebe Lake to about 25 feet in thickness on the south shore of Kashaweogama Lake. No granite boulders were identified. In the same member on the east shore of Iron Lake is an excellent exposure of arkosite which shows cut and fill structure and cross-bedding.

Conditions of deposition.—The sediments are well sorted, occur in persistent narrow bands which commonly show gradation from sandy material to silt and clay, and show little evidence of chemical alteration before deposition. They are underlain by thick conglomerates which are interpreted as continental deposits. The character of the sediments, with the exception of the iron formation, and their relation to the underlying thick conglomerates is very similar to that found in the Sioux Lookout area, about which Pettijohn says:

The upper part of the Abram series differs from the lower part in that it shows a greater lithologic diversity, different sedimentary structures, better sorting and scarcity or absence of larger fragments. In view of the probable continental origin of the conglomerate beds of the lower formation and of the characteristics of the Abram graywackes and slates, it is likely that the latter were deposited in fresh waters and that the cyclic alternation of types corresponds to periodic flooding, perhaps annual, of the area. The deposits of clay, silt, and impure arkosic sands alternate with great frequency, with seasonal changes. The deposits being continental, there is an absence or scarcity of limestone. . . . In so far as pyroclastic rocks occur they represent a contamination of flood plain deposits. The incomplete weathering and sorting of the graywackes and arkosites and the variability of the section would be more consistent with fresh water and continental origin than with marine origin.¹⁶

¹⁶ "Conglomerate of Abram Lake, Ontario, and Its Extensions," *Geol. Soc. Amer. Bull.* 45 (1934), p. 501.

Allowing for the derivation of sediments in the Savant area from a source which furnished dominantly acid and intermediate volcanic material as reflected in the peculiar composition of the graywackes and the scarcity of true arkosite and quartzite, it is very probable that the sediments of the Savant Lake area were deposited under essentially the same conditions as those in the Sioux Lookout area.

In the preceding portions of this paper it has been assumed that the ferruginous material of the iron formation was in the sediments in which it is now found at the time of, or soon after, their deposition. On this assumption the finer-grained sediments of the Savant series were subdivided into four members on the basis of presence or absence of iron formation. There is evidence, however, which suggests the possibility of introduction of the ferruginous material long after the deposition of the sediments through selective replacement by hydrothermal solutions.

The possible epigenetic origin of the iron formation is most strongly suggested by the microscopic examination. The presence of considerable introduced, unfractured tourmaline in the clastics, especially the argillite, implies the circulation of hydrothermal or pneumatolytic solutions through the rocks subsequent to their deformation. Original clastic structures truncated by magnetite metacrysts show that some movement of the ferruginous material took place subsequent to deposition. The siliceous character of the iron formation, when contrasted with the deficiency of quartz in the interbedded sediments, might be the result of epigenetic introduction of the silica. The great apparent thickness of the lower iron-bearing member off the nose of the Grebe-Pickerel Lake granite is also suggestive, though it might be explained equally well by an unconformity between the lower iron-bearing member and the overlying graywacke member. These four points, namely, the presence of hydrothermal solutions, some movement of the ferruginous material, high silica content, and areal distribution, do no more than suggest the possibility of epigenetic introduction of the iron.

On the other hand, it has been shown that the distribution of the iron formation is such that it composes two mappable units, an upper and a lower iron-bearing member separated by a non-iron-bearing graywacke member. This limitation of the iron formation to

specific stratigraphic horizons, coupled with the petrographic similarity of the clastic material of all of the finer-grained sediments (and, therefore, their equal opportunity for replacement if such replacement took place) and the delicate, persistent, interbedded character of the iron formation, is strongly suggestive of syngenetic origin.

If the iron formation is a syngenetic deposit, as seems most likely, there are several features which merit further discussion. Moore has noted that the iron formation is closely associated with igneous rocks. The writer has been unable to locate the interbedded flows described by Moore,¹⁷ but does recognize not only the existence of tuffs but also the peculiar, quartz-deficient character of the interbedded graywacke. The ferruginous material, if not derived from volcanic emanations, was probably furnished by the disintegration of acid to intermediate rocks.

Moore and Maynard¹⁸ show that electrolytes, present in the concentrations found in sea water, and certain types of bacteria are effective in precipitation and deposition of iron. It should be noted, however, that the sediments of the Savant Lake area are probably of fresh-water origin. Furthermore, the iron formation was formed as the upper member of varvelike couplets which show perfect gradation from graywacke, through argillite, to iron formation. Sauramo¹⁹ has shown that under present conditions varved structures showing gradation of grain do not form in salt water due to flocculation of the finer constituents by electrolytes. Therefore it is doubtful whether the Savant iron formation was formed through precipitation by electrolytes in sea water. On the other hand, no remnants of organic structures have been found.

It would be possible, however, to have the iron precipitated by electrolytes in lacustrine deposits through recurrent (perhaps seasonal) evaporation of the fresh-water lakes in which the sediments were deposited. During the greater part of the cycle the water

¹⁷ "Lake Savant Area, District of Thunder Bay," *loc. cit.*, p. 82.

¹⁸ E. S. Moore and J. E. Maynard, "Solution, Transportation and Precipitation of Iron and Silica," *Econ. Geol.*, Vol. XXIV (1929), pp. 277-79.

¹⁹ Matti Sauramo, "Studies in the Quaternary Varved Sediments in Southern Finland," *Bull. Comm. Geol. Finlande*, Vol. LX (1923), pp. 91-98.

would be fresh, and ordinary varved structures might be formed; but as concentration occurred, the iron might be precipitated during the later stages of the cycle.

HANDY LAKE VOLCANICS

Distribution and thickness.—Lying stratigraphically above the upper graywacke member and forming the center of the Savant synclinatorium is a very thick series of tuffs, agglomerate, porphyritic rhyolite, rhyolite, other acidic volcanic rocks and conglomerates, grits, and finer-grained sediments derived from them, which are grouped together and distinguished as the Handy Lake volcanics. This series is best exposed between the South Arm of Savant Lake and Lower Pickerel Lake, where the volcanics have an estimated thickness of 10,000 feet. From the data available at present the formation seems to be divisible into a basal tuff which grades up into a member composed dominantly of porphyritic rhyolite. Above, and perhaps in part contemporaneous with this flow member, is a member composed dominantly of conglomerate and agglomerate apparently derived from the underlying material in large part.

The lower tuff member is best exposed between the South Arm and the west line of Jutten Township. It is schistose and appears more highly weathered than most sedimentary rocks of the area. The middle flow member is typically exposed between Handy and Lower Pickerel lakes and has been studied in some detail by Moore,²⁰ who found that the rocks along the portage between the two lakes vary from porphyritic rhyolite to dacite. Study of a series of thin sections collected along the same portage by the writer confirms Moore's work.

The agglomerates and conglomerates of the Handy Lake volcanics appear to have a very erratic distribution. They are best exposed on Grebe and Upper Pickerel lakes, where they appear as bedded deposits interstratified with arkosite, graywacke, and grit. This member apparently continues westward.²¹

The contact between the Handy Lake volcanics and the upper graywacke member may be observed along the west end of the

²⁰ "Lake Savant Area, Thunder Bay District," *loc. cit.*, p. 63.

²¹ *Ibid.*, p. 63.

Grebe-Savant Lake portage. There is no pronounced angular unconformity between them at this point. In the southern part of the map area the Savant series is greatly reduced in thickness and the basal contact of the volcanics appears to be transgressive. Until the structural relations, particularly the faulting, have been worked out in greater detail, it is impossible to determine the magnitude of any unconformity that may exist.

BASIC INTRUSIVES

Basic dikes and small intrusions of diorite and metadiorite were found. The largest area of metadiorite occurs on the east end of Upper Pickerel Lake as a triangularly shaped mass about $1\frac{1}{2}$ miles long and less than $\frac{1}{2}$ mile wide at the east end. Near the granite it is a coarse-grained, massive, granitoid, dioritic-appearing rock, but farther from the granite it is less metamorphosed. Under the microscope its original dioritic character is quite apparent.²²

As noted on page 466, the mass of diorite forming a portion of the north shore of Kashaweogama Lake is thought to be extrusive rather than intrusive. The intimate association of the diorite with basic tuffs, the elongated, narrow outcrop of the diorite, and the discovery of structure suggestive of ellipsoids, form the evidence for the change in interpretation.

Several large basic dikes and numerous small dikes were mapped. In most cases the dike relation was clear, either because of cross-cutting relation to the intruded beds, because of narrow widths, or because of coarseness of grain at both contacts.²³

The time of intrusion of most of the basic rocks can be definitely determined. Those intruded into the Savant series must be post-Savant series in age. Those cut by quartz veins are probably pre-granite in age. This post-sedimentary, pre-granite age relation has

²² A portion of this mass was mapped as Keewatin, a part as sedimentary, by Moore (1928).

²³ One dike located on an island in the extreme northeastern corner of the map area is of particular interest due to the inclusion of a number of cobbles and pebbles of granite and vein quartz and a large amount of rounded, unassimilated silicic material of sand size. The included material appears to be derived from the conglomerate which underlies the sediments into which the dike was intruded.

been found in other areas in northwestern Ontario; and the rocks are referred to as "Haileyburian" by Watson.²⁴

ACID INTRUSIVES

With the exception of the area north of Kashaweogama and Iron lakes, granite and porphyritic granite were found to have essentially the area distribution shown by Moore.²⁵ North of Kashaweogama and Iron lakes, however, the granitic intrusives are much less extensive than formerly mapped and are limited to a small stock near Heron Lake and a stock or border of a batholith north of Iron Lake, the rest of the area formerly mapped as granite being greenstone and conglomerate. A small number of dikes of granite, aplite, and rhyolite-porphry were also found.

The petrographic study of the granitic rocks, though limited to a few thin sections from each mass, shows differences in texture, mineral assemblages, and degree of shearing and fracturing sufficient to characterize each mass, at least in the area studied. The porphyritic mass north of Iron Lake is characterized by its fresh and massive appearance and by the very large euhedral phenocrysts of pink orthoclase which average about $1\frac{1}{2}$ inches in length.²⁶ The Grebe-Pickerel Lake stock appears to be almost identical in mineral assemblage, degree of shearing, and alteration with the Iron Lake mass, but is not porphyritic. Locally it is more highly sheared. The Heron Lake mass may be distinguished from the other granites by the extreme alteration of the feldspars and by the microscopic augen structure with quartz as the interaugen material. The Jutten Lake granite is characterized by the extreme granulation of the essential miner-

²⁴ R. J. Watson, "Platinum-bearing Nickel-Copper Deposit on Lower Shebandowan Lake, District of Thunder Bay," *Ont. Dept. Mines*, Vol. XXXVII, Part IV (1928), pp. 133-34.

²⁵ "Lake Savant Area, District of Thunder Bay," *op. cit.*, pp. 53-82.

²⁶ Of special interest in this mass is the variation in the development of the large orthoclase phenocrysts near the contact with conglomerate on the little lake north of Iron Lake. Dikes up to four inches in width have no phenocrysts. As the width of the dike increases, the phenocrysts increase in size until above an eight-foot width the phenocrysts are about an inch in length. This relation seems to indicate that the magma was in a very fluid condition with few crystals and no phenocrysts at the time of its intrusion. The granite, however, produced very little alteration in the conglomerate, pebbles and cobbles being readily distinguishable a few inches from the contact.

als and can be differentiated from the other granitic rocks of the map area by this characteristic and its darker color in the hand specimen. These suggested differences are, of course, tentative; and petrographic study of larger suites of samples, perhaps supplemented by a study of the heavy accessory minerals, should be made.

As pointed out by Moore, granites of two quite different ages have existed in this portion of northwestern Ontario. Granite boulders in the lower conglomerate member of the Savant series must have been derived from a granite older than that series. The Grebe-Pickerel Lake stock and the porphyritic granite north of Iron Lake are definitely intrusive into the Savant series and are, therefore, younger granites. Both the Heron and Jutten Lake masses are intrusive into the Jutten volcanics, but the relation to the Savant series was not sufficiently clear to warrant their unreserved classification as younger granites. Because of Moore's classification of them as later than the Savant series and for lack of conclusive evidence of earlier origin they are here tentatively correlated and mapped as younger granites.

KEWEENAWAN (?)

In his study of the Savant Lake area Moore found basic dikes cutting the granites and referred them to the Keweenawan.²⁷ All basic dikes found by the writer in the map area either are cut by quartz veins and are, therefore, probably younger than the granites, or are not associated with such veins. But on a reconnaissance trip north on Savant Lake one large diabase dike was found cutting across the quartz veins and was, therefore, probably post-granite. It is possible that basic dikes of this area may be discovered within the limits of the map area.

PLEISTOCENE AND RECENT

Deposits of glacial origin are widely distributed. They occur mainly as fillings of basins of the bedrock surface, but in several places, namely, between Jutten and Savant lakes, south of Kasha-weogama Lake and north of Iron Lake, form well-defined ridges, probably moraines. The drift has been more fully described by Moore.²⁸

²⁷ "Lake Savant Area, District of Thunder Bay," *loc. cit.*, p. 65.

²⁸ *Ibid.*, p. 65.

CORRELATION

The custom of students of the pre-Cambrian of northwestern Ontario is to correlate the rocks of the various "schist belts" on the basis of lithology, stratigraphic sequence, and the relation of the extrusive rocks and the sediments to the granitic intrusives. Nearly all of the greenstones have been called Keewatin; and when overlying sedimentary beds are present, they have been correlated with the Timiskaming. Granites which intrude the sediments are called Algoman. In many cases no evidence is given for such correlation, and in most other cases the evidence which is presented does not warrant the conclusions derived from it. About twenty-five years ago these same rocks were correlated unhesitatingly with the Keewatin, Huronian, and Laurentian.

The rocks of the Savant Lake area were correlated with the Keewatin, Huronian, and Laurentian up to 1928 by all geologists who worked in the area. In 1928 Moore stated in regard to the granitic intrusives:

. . . there is no way of determining the true age of this granite at present, but it seems probable that it may be Algoman. . . . In the earlier report, mentioned above [1910], the granite and granite gneiss were mapped as Laurentian according to the custom of the day among many geologists.²⁹

Concerning the correlation of the greenstones and sediments, he noted:

Following the ordinary procedure in classifying formations according to age, the main conglomerate should be considered as indicating a great unconformity and, together with the younger associated rocks, as belonging to the Timiskaming or some age other than Keewatin.³⁰

In 1929 the same writer³¹ definitely correlated the sediments of the Savant Lake area with the Timiskaming on three kinds of evidence, namely, high degree of folding, presence of a prominent basal conglomerate containing boulders and pebbles of granite, and varve-like banding of the sediments. The correlation may be correct, but the writer prefers to use local names until such time as general names can be applied with more certainty.

²⁹ *Ibid.*, p. 64.

³⁰ *Ibid.*, p. 57.

³¹ E. S. Moore, "Keewatin-Timiskaming Boundary," *Geol. Soc. Amer. Bull.* 40 (1929), pp. 547-56.

There are two areas, however, with which some comparisons may reasonably be made, the Sioux Lookout area, which lies about 75 miles to the west, and the Sturgeon Lake area, which is about 30 miles to the south. The former area has been extensively studied during the last seven years by Pettijohn,³² who found a thick series of greenstones, overlain unconformably by thick conglomerate and arkose. This, in turn, is overlain by a series of banded fine-grained sediments interbedded with some pyroclastics and perhaps some volcanics. Above this dominantly sedimentary sequence is a thick series of pyroclastics and volcanics of unknown thickness. Reference to the accompanying correlation chart shows that there is apparently a marked similarity between the larger units of the Savant Lake and Sioux Lookout areas, but in detail the relationships are less clear.

In the Sturgeon Lake area less detailed work has been done. Sediments have a limited distribution, as has a band of rhyolite and pyroclastics. The former may be the time equivalent of the Savant and Abram conglomerates; the latter may be the equivalent of the Handy Lake volcanics or perhaps the Patara series.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The structural geology of the Savant Lake area is very complex. That the area is a portion of a great synclinorium was recognized by Moore,³³ but that those intensely folded rocks were also cut by numerous faults of great displacement was not considered probable by him. The writer proposes to review briefly the evidence for folding and then to discuss the evidence for five of the most important faults. The faults that have been found and described are important, but it is believed that several more of similar or greater magnitude will probably be found.

FOLDING

Moore's conception of a central mass of fine-grained sediments, volcanics, and pyroclastics flanked by two converging bands of conglomerate, and these in turn flanked by areas of greenstones, must be

³² "Conglomerate of Abram Lake, Ontario, and Its Extensions," *Geol. Soc. Amer. Bull.* 45 (1934), pp. 479-506.

³³ "Lake Savant Area, District of Thunder Bay," *loc. cit.*, pp. 65-66.

TABLE II
CORRELATION OF THE SAVANT LAKE AREA WITH THE SIOUX
LOOKOUT AND STURGEON LAKE AREAS

Savant Lake Area			Sioux Lookout Area*	Sturgeon Lake Area
Pleistocene			Pleistocene	Pleistocene
Unconformity			Unconformity	Unconformity
Keweenawan (?)			Granitic and basic intrusives	Granitic and pregranitic intrusives
Unconformity				
Granitic intrusives				
Basic intrusives			Neepawa volcanics (tuffs and flows)†	Basic volcanics (?)‡
Handy Lake volcanics				
Unconformity (?)			Unconformity (?)	Unconformity (?)
Savant Series	Upper	Upper graywacke member	Abram Series	Daredevil formation (iron formation, interbedded sediments and tuffs)
		Upper iron-bearing member		
		Lower graywacke member		
		Lower iron-bearing member		
	Lower	Upper conglomerate member	Ament Bay formation (conglomerate and arkosite)	Conglomerate and graywacke§
		Lower conglomerate member		
Unconformity			Unconformity	Unconformity (?)
Intrusives (?) (granite pebbles in conglomerate)			Intrusives (quartz-porphry, metadiabase and meta-diorite. Granite pebbles in conglomerate)	Intrusives (?) (granite pebbles in conglomerate)
Jutten volcanics			Gray "greenstone"	Basic volcanics (?)‡
			Patara series	
			Green "greenstone"	

* Specifically Vermilion Township.

† East Bay, Minnitaki Lake.

‡ Assigned to "Keewatin" by Graham, but may be of two ages as indicated.

§ Not confirmed by Tanton.

|| This series mapped by Hurst as Temiskaming conglomerate.

somewhat modified in the light of the writer's work, but, nevertheless, is probably essentially correct. The tops of the Jutten volcanics north of Kashaweogama Lake face away from, not toward, the axis of the synclinorium. There is strong evidence that the contact of these beds with the conglomerate to the south is a fault contact. Determination of top of beds by gradation of grain, cross-bedding, and cut-and-fill structures indicates that the top of the conglomerate, as well as that of the finer-grained sediments to the south of the conglomerate, does face the center of the synclinorium.

On the South Arm, the tops of the Jutten volcanics all face northwest, as do the tops of the overlying conglomerates. The structure of the finer-grained sediments, however, is more difficult to interpret, especially north and west of the narrows between Savant Lake and the South Arm, where the iron-bearing members are highly contorted.

The original attitude of the sedimentary and extrusive rocks in the map area must have been very near to the horizontal. Owing to the folding of the rocks, however, they are now all essentially vertical, or, as near the South Arm, somewhat overturned. No dips less than 65° were noted at any point in the map area.

FAULTING

One of the most important faults for which there is considerable evidence separates the Jutten volcanics and the Heron Lake stock from the conglomerates north of Kashaweogama Lake and Wiggle Creek (Fig. 2). As noted above, structural determinations by means of pillow structure show the top of the greenstone to the north. Only six determinations were made, but they all agree. Near Heron Lake greenstone is intruded and considerably metamorphosed by the Heron Lake granite. The adjacent conglomerates are not cut or metamorphosed by the intrusion. The Heron Lake stock has several gneissic zones parallel to the supposed fault, and the greenstone and the granite to the north and the conglomerate to the south are everywhere separated by low ground along the line of the fault. The conglomerate shows great reduction in thickness from east to west; but it is the lower, not the upper conglomerate, that is so reduced (Fig. 2). Since the conglomerate and greenstone now lie "bottom to bottom" on opposite sides of the fault, the amount of displacement was

probably considerable. If the fault plane dips at a high angle, it is difficult to conceive how a vertical movement could result in the "bottom to bottom" relationship. For this reason it is believed that the displacement was probably horizontal.

In this same area there are several north-south cross faults which displace the strike fault mentioned above. The most important of these is located north and slightly east of Kashaweogama Lake. Four others were found between that point and the west line of the map area. All are postulated because of offset relations of the conglomerate and greenstone in this area (Fig. 1).

A second area in which faulting is prominent but in which the relations are less clear is the neighborhood of the South Arm of Savant Lake. The existence of an east-west cross fault just south of the narrows between the main lake and the South Arm is required to explain the sudden ending of the iron-bearing members at that place and also to explain the disappearance and change of strike of the lower conglomerate member between MacNamara Point and the north shore of Stillar's Bay.

A strike fault (northeast trend) probably follows the center of the South Arm, separates the iron-bearing member from the conglomerate at the narrows, and then forms the iron-bearing member-greenstone contact through the main lake. In the South Arm the strike of the beds on the west shore is about N. 35° W. Graded bedding indicates that the top of the beds is to the east. On MacNamara Point the conglomerate strikes N. 20° E., and the top of the beds is to the west. At the narrows the iron-bearing member, in contact with the conglomerate, strikes N. 20° E., whereas the adjacent conglomerate strikes east-west. On the main lake the iron-bearing member is highly contorted and the strike of the individual beds cannot be determined, but the conglomerate members are missing. These discordant relations strongly suggest a fault.

The eastward-striking conglomerate on the north shore of Stillar's Bay was interpreted by Moore as possibly the result of folding. Moore notes that

... the main syncline was formed first and that pressure was later applied from the north and south and that the lava flows in this zone were tipped into a vertical position and schisted, with the strike running nearly east and west.³⁴

³⁴ *Ibid.*, p. 67.

The writer believes that this is probably a partially rotated fault block. Moore's theory would not explain the greenstone in the northern part of this area which was mapped by him as conglomerate.

Three small east-west faults south of the South Arm are indicated by the offsetting of the members of the Savant series and by the very narrow watercourses in Jutten township with which they are aligned. The structure in the area north of the Iron-Savant Lake portage is still not understood. That some faulting has taken place is shown by the occurrence of conglomerate and the iron-bearing member in strike line with one another, separated by only a hundred feet or so of covered ground. That there has also been folding is shown by the folding of the iron-bearing member on the portage.

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